United Nations Industrial Development Organization

Distr.
LIMITED
ID/WG.437/4
6 February 1985
ENGLISH

National Meeting on Applications
of Microelectronics and Software

Nairobi, Kenya, 18 - 23 February 1985

THE PROSPECTS FOR SOFTWARE PRODUCTION IN DEVELOPING COUNTRIES*

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V.85-22044

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INTRODUCTION

This paper deals with the advancement of the information industry, particularly of the software industry in developing countries. In the first part three phases of information system development are distinguished. The successful implementation of one phase is considered to be a prerequiste for the start of the following phase. In the final part concrete policy recommendations relating to the software sector are presented.

In the long term, any industrial activity can only be successful if it is satisfying the needs of the people. This general observation applies to the information industry as well as to any other industrial sector.

The development of the Information Industry in any country must therefore be coordinated with the general industrial development and must contribute its share to the national priorities.

In the developed countries, the information industry is one of the most important economic growth sectors. Its main contributions are in the area of business operations, however it is also directly affecting many other spheres of the society, e.g the education system, the communication patterns and the consumption of information and entertainment in the home.

The importance of the information sector for the advancement of a society, developing as well as developed, cannot be overstated. The information industry is primarily a knowledge based industry. Therefore the availability of skilled technicians and wellinformed experts is more important for the development of this industry than large capital resources. The most important aspect of information technology development is knowledge generation. It follows that different policy actions are relevant depending on the level of development a society has achieved so far.

It is inappropriate for this author to define the national objectives and the role of the information technology in this context. However, it will be shown that the advancement of the information industry critically depends on a number of preconditions which must be realized in each phase of development.

This paper is subdivided into two parts. In the first part we will introduce three phases in the development of the information industry and discuss the resources required to implement each phase. Based on this analysis, we will outline concrete recommendations for a software policy in the second part.

REQUIREMENTS OF THE INFORMATION INDUSTRY

In the development of the information sector of the economy we distinguish between the following three phases.

(1) Introductory phase

In this phase basic know-how in the area of information technology is built up. This is achieved in a number of different ways. On the one side a core group of experts acts as a catalytic element for the dissemination of basic knowledge which is acquired from outside sources. On the other side a base of skilled technicians has to be established in order to accept and transform this know-how to information technology products which are useful for the home market. It is felt here that application software development on small microcomputers forms an ideal entrance to this first phase. Microcomputers are relatively cheap and therefore do not require much capital. The maintenance of microcomputers is much simpler than the maintenance of large machines. The growth rate of the microcomputer market is significantly higher than the growth rate of the computer industry in general. It is to be expected that by the end of 1986 the world market for microcomputer based desktop systems will surpass the the general purpose computer market. Thus the introduction of the small mass produced microcomputer corresponded to a "technology break" which will transform the information industry in general. Nations which enter the information era now can take advantage of the challenge provided by such a technology break.

The knowledge required to get the microcomputer to practical use is small compared to the knowledge required to operate and maintain the large machines. Thus it is to be expected that the results of an application software

product development will be visible and available within a fairly short period of time.

The selection of the right application area for these pilot projects in application software development is of crucial importance for the success of the introductory phase. Only if the products are contributing to the national priorities the support of this first phase will be guaranteed on a wide and undisputed base.

In a nation, which considers self sufficiency in food and the advancement of education as its primary goals, the application software products should be based on the needs in this area. For example, a small microcomputer based software package can help a farmer to calculate the optimal food composition for the animals or assist a warehouse in stock control. Small computers with the appropriate software packages can also be placed in schools in order to support the teachers and provide an environment for the advancement of general computer literacy.

The data exchange between these stand alone microcomputer systems should be based on the exchange of the data storage media, e.g. floppy discs. Depending on the availability of a communication infrastructure, the direct interconnection of these small computers should be investigated by the core group. However, since the operation of a reliable data communication service is a difficult task, no application should be dependent on the availability of such a service in this first phase.

The wide availability of these small microcomputer systems can form the starting point for a local hardware maintenance service. Although maintenance will be limited to component replacement at first, this can form the nucleus of a small hardware industry, e.g. the design and manufacture of some peripheral devices. It is very important that the core group of experts does have sufficient knowledge in such practical areas as hardware maintenance and design and is obliged to support small enterpreneurs willing to enter this new field.

The resources required to implement this introductory phase are the following:

- A core group of 10 to 20 experts which are knowledgeable in the fields of computer applications, software design, hardware maintenance and hardware design. The implementation of the first pilot projects is the responsibility of this core group. This core group is also responsible for the selection of application areas and user education.

- Capital in order to provide the core group with computers and a state of the art software development environment and a sufficient number of personal computers to operate the application software at the end users. The equipment which is necessary in order to test and maintain the microcomputers must also be provided.

(2) Intermediate phase

In addition to the delivery of useful application software products the most important result of the first phase is "know how generation" in the area of computer literacy in general, programming, hardware maintenance etc.. The widespread availability of this know how is a prerequisite for entering the second intermediate phase of development. The second phase of this development plan is more know how and capital intensive than the first phase. Only after a sufficient number of skilled technicians has been trained in the first phase and a general insight into the benefits and limits of computer applications is available among a sufficiently large number of potential end user does it make sense to enter this intermediate phase. Otherwise the significant capital resources, which are required for this second phase will not be used to their full potential.

This second intermediate phase can be considered the "core" phase of information system development. On the software side, the many small microcomputer systems should be interconnected, both offline and online to realize synergetic effects. Some central data bases will be built to support the decision making of the government and industry. Know-how in the operation of large computers with complicated operating systems and telecommunication systems has to be acquired. An important application area which has to be entered in this second phase is the development of real time systems for data collection and process control. These real time systems can improve the operation of industrial plants, thus reducing the material and energy consumption and the pollution. In our opinion it is important for the developing

countries to be sensitive about pollution effects to the environment at an early stage so that the immense capital resources which are required to clean up the environment after it has been polluted can be saved. Computer technology, particularly real time control of industrial processes can contribute significantly to realize these goals.

The software development in this second phase will not be limited to application software development. Real time control requires an insight into operating systems, data communication and man machine interactions. These capabilities should be introduced and realized in pilot projects by the core group of experts which must be expanded in this second phase.

On the hardware side the maintenance activities can be expanded into a small computer industry with the capability to assemble and later on design microcomputer system at the Printed Circuit board level with standard components. A joint venture with one of the computer companies which supplied the microcomputers of the first phase is an effective way of technology transfer. In the second phase the economy can achieve a fairly high level of self-reliance in the area of information technology. Components are bought from the world market (they only represent a small fraction of the value of a complete computer application), assembled, programmed and maintained within the country. Most of the value of information system development will be added within the country.

At the end of the second phase, after a sizeable home market for hardware products has developed and enough expertise in hardware design, assembly and testing has been acquired, the Very Large Scale Integration (VLSI) field for the production of microelectronic components can be entered. Two stages must be distinguished when entering the VLSI field. The first stage comprises the design of VLSI components only. At this stage the production is still with some outside supplier, i.e. a "silicon foundry". In the second stage the production of VLSI components is also accomplished within the country. It is strongly recommended here not to start the production of VLSI components until a wide market and sufficient know-how in the design of VLSI circuits is available. Therefore VLSI production should be left to the advanced phase of information technology development.

The resources required for this second phase of information technology development are substantial:

- Information system technology must be integrated into the education system at all levels. Information system topics should be included in the general education in order to increase the awareness for the benefits and limits of computer technology and thus increase the "computer literacy" of a wide audience. The training of skilled technicians at the intermediate level in vocational training schools is of utmost importance. At the University level "centers of excellence" must be created for the training of the teachers and for keeping contacts with the international research community. The core group of experts for the introductory phase will form the nucleus for these "centers of excellence" and has to be expanded to cover all topics which are introduced in the second phase of development.

- Marketing channels to sell the information system products produced locally must be established. The maintenance organizations must be expanded to cover all products introduced in the second phase, software and hardware. Policy actions, which limit the variety of products can help to reduce the maintenance effort and increase the productivity of the normally scarce skilled labor force.

(3) Advanced phase

The know-how acquired and generated during the intermediate phase is a prerequisite for a successful start of the final, the advanced phase of information technology development. In this phase of development the information sector matures to a level which corresponds to the state of the art of information technology worldwide. In the industrial sector, information system products (hardware and software) will be exported under international competitive conditions. In the academic sector the "centers of excellence" contribute and expand the international state of the art of information technology.

On the software side the development of complex real time systems and expert system is characteristic for this third phase. A fully developed and reliable communication infrastructure is a prerequisite for the interconnection of the different decentralized computer systems. Electronic mail and office automation systems gain widespread acceptance. A high percentage of the work force will be using the computer systems in one way or another.

On the hardware side, the home production of the VLSI components, which have been developed in the second phase is started. The technical infrastructure which is required for the successful fabrication of VLSI components is enormous. The continued maintenance of the complex mechanical and electrical equipment which is necessary for VLSI production requires a large number of very skilled technicians. The media (liquids, gases) required for microelectronic factories must conform to the highest quality standards. If the quality of the clean room environment is not maintained, serious production losses will result.

The following table gives an overview of these three phases of information technology development:

Phase	Software	Hardware	Infrastructure
Introductory	Application Software on Microcomp. Data exchange via media	Microcomputer acquired from outside	small core group of experts maintenance capability developed
Intermediate	Database appl. Real time communication System Softw.	Assembly of small computers and Peripherals VLSI design	Education at all levels Centers of excellence created
Advanced	Complex Real Time systems Expert system	VLSI production	Communication infrastructure High level of general technical infrastructure

POLICY GUIDELINES

The information policy which has to be formulated and executed in a country depends on the level of the information sector. In the following we will concentrate on policy guidelines for the introductory phase of information system development, as outlined before.

In this phase the application software development on Microcomputers is the first and primary activity. The following topics have to be addressed

-Software development center
-Economic climate
-Education
-Standards

(1) Software development center

A small and effective group of experts forms the starting point for the national software effort. This group of experts should be located in a Software Development Center which is responsible for the specification of a detailed software development plan, for the implementation of pilot projects and for the training of teachers, programmers and end users.

These experts can be recruited from local people who have been trained in suitable environments within the country or abroad or from outside consultants. It is important that the skills in this core group of experts are practical as well as theoretical. In addition to a solid background in software engineering these people should also have project management experience, communication, didactic and legal skills. A small number of the people in the core group should also be hardware oriented, as mentioned before. The expertise in this core group should be sufficient to program and maintain the computer systems which have been selected.

At the beginning, this core group of experts should be located in a Software Development Center with the necessary equipment for Software Development. Such an equipment consists of workstation Microcomputers and a software development environment. The necessary equipment for hardware maintenance to the printed circuit board level should also be provided.

In addition to the implementation of pilot projects, the Software Development

Center should provide the following services:

- Monitor the market of information industry products and new trends and developments. This will provide valuable background information, both for the political decision makers and software developers.

- Formulate and, after approval, execute an initiative to promote general "computer literacy". A necessary prerequisite for the success of a new industry, such as software, is a general public awareness for the potential, the capabilities and the risks involved.

- Initiate a research program on information science and specifically on software technology.

- Support interested individuals and startup companies in the area of software technology with economic and legal advise, as well as with some financial assistance.

- Set up the legal framework for the introduction and execution of standards for the information industry. Standardization of hardware, software and the associated documentation can substantially reduce the maintenance costs for information industry products and improve the compatibility of the different systems.

(2) Economic Climate

If we analyse the world-wide market for application software, we will find out that this market has some characteristics of a "cottage industry". Small companies and sometimes even single consultants play an important role in this market. If the startups in the area of application software are to be successful, it is necessary to provide a climate in which such a "cottage industry" can blossom.

In addition to the technical support which is given to these new entrepreneurs by the Software Development Center the legal and financial climate must be such that motivated people are willing to take the risk of forming their own small company for software production or computer system maintenance.

The rules and regulations concerning software acquisition by the government or other public organization should encourage small local companies to participate in software projects.

(3) Education

An important result of an active Information Policy is the general advancement of computer literacy in a society.

It must be the goal of a computer literacy initiative to bring a high percentage of the youth in direct contact with computers and software at an early age. Personal computers should be installed in all schools and students in the age of ten upwards should have the possibility to use these machines in their mathematics and science classes. Experience has shown that students of that age have no problem in mastering the computer. If there is some lack of trained teachers, computer assisted instruction courses, which run on these small machines, can fill part of the gap. Students, which thus develop a natural relationship with the computer, will have no difficulty in integrating the computer into their workplace at a later stage.

While it is important to introduce computers into the general education system as early as possible, the retraining of parts of the active workforce must not be overlooked. Many job profiles are changed because of the introduction of computers. It is irresponsible to fill new job positions with new people only and to push those workers, who do not have the necessary knowledge in the new technologies, aside. The persons, who have worked in a given position for a number of years, have gained valuable job experience which, combined with some software knowledge, is an important asset to society. The computer and software training of the adult population must thus be included in the training programs.

Teaching computer and software technology without the possibility of practical work on the machine is a dangerous undertaking. Since the lectures tend to become too theoretical, the student will not grasp the elementary concepts and might shy away instead of developing a positive attitude towards this new technology.

Therefore any software education initiative must be supported by an initiative to provide the necessary computer hardware for the practical software training on the machine. As mentioned before Microcomputers form the recommended hardware base for this practical training. A detailed outline

for a software engineering curriculum is contained in the UNIDO report referenced below.

(4) Standards

At the moment, there are so many different companies offering microcomputer systems and software that some restraint is necessary. Otherwise the effort for training and maintenance will become unacceptable.

In the first phase of the information sector development only a small number of information system products should be included in a national standard.

The standards should cover the following areas:

- Microcomputer Hardware and Peripherals
- Operating Systems
- Programming Languages
- Data Communication Protocols.

A detailed discussion of these standards is contained in the UNIDO report "Guidelines for Software Production in Developing Countries" by H. Kopetz, UNIDO/IS. 440 February 10, 1984.

POLICY RECOMMENDATIONS

(1) Establish a core group of 10 to 20 experts with theoretical and practical expertise in the following fields: software engineering, hardware maintenance, application know how, application software development, organizational and legal skills.

(2) Select a small list of Microcomputer models. Evaluate the models and standardize on two or three. Standardize the operating system and programming language.

(3) Establish a maintenance organization for the standardized hardware. This can be in cooperation with small industry. It is important that the training and spare parts for this maintenance organization are fully secured.

(4) Identify an application area which is at the center of the national priorities and which can be effectively supported by a standalone Microcomputer application.

(5) Initiate a pilot project on application software development in the selected application area with strong user participation. Closely monitor the progress of this project. After completion of this project implement the application on a broad scale. It is important to provide excellent user documentaion, end user training and a "hot line" for maintenance in hardware and software.

(6) Provide a large number of the selected Microcomputers to the Educational Institutions, i.e. Universities and vocational training schools. The cooperation between these educational institutions and the core group is to be established.

(7) Establish a training program for software engineers and teachers at the University. Introduce courses on computer programming and software development into the vocational training schools. All courses must have a substantial section of practical laboratory work.

(8) Initiate a program for the financial, organizational and legal support of independent software consultants and small companies. Provide these institutions with the selected microcomputer equipment. Support these institutions with free training courses.

(9) Ascertain that the acquisition of software and computer systems by the government and other public or semipublic agencies is open to these small entrepreneurs.

(10) Establish regional centers for information technology. Introduce a research program in software technology. Initiate a "computer literacy campaign" at all levels of the educational system.